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STS-33 NATIONAL SPACE TRANSPORTATION SYSTEM MISSION REPORT

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NATIONAL SPACE TRANSPORTATION SYSTEM

MISSION REPORT

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INTRODUCTION

The STS-33 National Space Transportation System (NSTS) Mission Report contains a summary of the vehicle subsystem activities on this thirty-second flight of the Space Shuttle and the ninth flight of the OV-103 Orbiter vehicle (Discovery). In addition to the Discovery vehicle, the flight vehicle consisted of an External Tank (ET) (designated as a ET-38/LWT-31), three Space Shuttle main engines (SSME's) (serial no. 2011, 2107, and 2031), and two Solid Rocket Boosters (SRB's) (designated as BI-034).

The STS-33 mission was a classified Department of Defense mission, and as such, the classified portions of the mission are not presented in this report.

The sequence of events for this mission is shown in Table I. The report also summarizes the significant problems that occurred in the Orbiter subsystems during the mission, and the official problem tracking list is presented in Table II. In addition, each of the Orbiter problems is cited in the subsystem discussion within the body of the report.

The crew for this thirty-second flight of the Space Shuttle was Frederick Gregory, Col., USAF, Commander; John E. Blaha, Col., USAF, Pilot; Manley L. Carter, Cmdr., USN, Mission Specialist 1; Story Musgrave, M.D., Ph.D., Mission Specialist 2; and Kathryn Thornton, Ph.D., Mission Specialist 3. This was the second flight for the Commander and Pilot, the first flight for Mission Specialist 1 and 3, and the third flight for Mission Specialist 2.

MISSION SUMMARY

The STS-33 mission was launched at 327:00:23:29.986 G.m.t. (6:23:30 p.m.c.s.t.) and the launch phase was satisfactory in all respects. The launch countdown proceeded nominally until T-5 minutes when a hold was called because of a minor ground purge-flow problem. Space Shuttle main engine and solid rocket motor ignitions occurred as expected and the launch phase performance was satisfactory in all respects. During ascent, auxiliary power unit (APU) 1 gearbox outlet pressure rose above 80 psia from its normal operating range of 55 to 60 psia. About 9 minutes after lift-off, the APU-1 gearbox pressure began decreasing, and within 2 minutes, the pressure had returned to the normal range. The minor problem had no effect on ascent performance.

Following APU shutdown after ascent, the hydraulics system 1 and 2 accumulator pressure locked up between 250 and 300 psid below the expected value. This phenomenon was observed on the last two flights of this vehicle, and the problem did not affect mission operations.

During the orbital maneuvering subsystem (OMS) -1 maneuver, the right OMS oxidizer quantity gauge indicated off-scale high; however, the gauge indicated properly during OMS-2 and only indicated improperly for 10 seconds of the deorbit maneuver. These erroneous readings did not affect the mission.

The waste collection system (WCS) commode control valve linkage failed, causing an overboard oxygen leak from the cabin. The leak was isolated by closing the commode slide valve. The crew performed an in-flight maintenance (IFM) procedure to manually operate the commode control valve and regained full operation of the WCS.

The Ku-band failed the self-test three times during the flight; however satisfactory communications were maintained when using the Ku-band. These failures did not impact mission operations.

The text and graphics system (TAGS) was activated and after a short period of nominal operation, a jam occurred. Malfunction procedures were performed, but did not clear the condition. The TAGS was powered down for the remainder of the mission and the teleprinter was used.

The crew reported at 328:10:55 G.m.t., that the Arriflex 16-mm camera failed to operate. An IFM was performed, but camera operation was not regained. However, at 329:05:45 G.m.t., the crew reported that the 16-mm camera was again operating.

The oxygen tank 1 check valve stuck twice during the mission when tank 1 was not in use. A 20-psid pressure difference built-up across the check valve before the valve opened and resumed normal operation. The nominal operating pressure is 3 to 5 psid. The anomaly did not affect the mission.

The crewman optical alignment sight (COAS) readings taken on flight day 2 and 3 varied by as much as 0.272 degree. This is similar to the problem that occurred on STS-29, the previous flight of this vehicle.

Just prior to the day 3 sleep period, the crew reported that water was not being dispensed by the galley. The crew performed a malfunction procedure and regained the water dispensing capability.

The APU-2 start for the successful flight control system (FCS) checkout occurred at 329:23:59:08 G.m.t., and APU 2 was operated for 7 minutes 26 seconds and 20 lb of fuel was used.

During the dedicated displays test of the FCS checkout, the Commander's Alpha/Mach Indicator (AMI) velocity value read 20,500 ft/sec instead of 20,000 ft/sec. Similar errors have been noted on previous flights of OV-103 (STS-26 and STS-29). A determination was made that these erroneous indications would not impact entry operations. Also during the reaction control subsystem (RCS) hot-fire portion of the FCS checkout, RCS thruster F1U failed off and was auto-deselected by the redundancy management (RM). All data except the chamber pressure (V42P1548A) indicated normal thruster operation.

The mission was extended for one day because of unacceptable wind conditions at the landing sites. As a result of the delay, the landing was scheduled for revolution 78 on Monday, November 27, 1989; however, weather conditions were unacceptable at that time and the landing was made on revolution 79. Consumables remained well above minimum redline values for the mission extension.

After completion of all final entry preparations, including stowage and payload-bay-door closure, the OMS deorbit maneuver was performed at 331:23:10:51.38 G.m.t., with a firing duration of 181.9 seconds and a differential velocity of 354.9 ft/sec. During the pre-entry and entry period, two APU exhaust gas temperature (EGT) sensors indicated off-scale. These failures did not affect entry operations. Also, the flash evaporator system (FES) shut down when the FES was reconfigured for entry. A successful restart was made, and the FES worked properly for the rest of the mission.

Entry interface occurred at 331:23:59:39 G.m.t. During entry, the backup flight system (BFS) was declared no-go because of erroneous altitude readings. This condition did not affect entry operations. The normal entry blackout period did not occur as communications were maintained through the TDRS-West satellite. Main landing gear touchdown occurred at 332:00:30:16 G.m.t. (6:30:16 p.m.c.s.t.) 1854 feet past the runway threshold on concrete runway 04 at Edwards Air Force Base, CA. Nose landing gear touchdown followed 10 seconds later and 2670 feet past the displaced threshold with wheels stop at 332:00:31:02 G.m.t. The rollout required 7764 feet and was normal in all respects. The crew completed the required postflight reconfigurations before egressing the vehicle.

Data were collected for ten of the thirteen development test objectives (DTO's) assigned to this mission. Initial indications are that the modular auxiliary data system (MADS) recorder functioned properly and data were collected for the six data-only DTO's. Initial reports indicate that all nine detailed supplementary objectives (DSO's) were accomplished.

SOLID ROCKET BOOSTER PERFORMANCE

All SRB systems performed as expected. The SRB prelaunch countdown was normal. The solid rocket motor (SRM) propulsion performance was well within the required specification limits and propellant burn rates for both SRM's were near normal. SRM thrust differentials during the buildup, steady-state operations, and tailoff phases were well within specifications. All SRB thrust vector control prelaunch conditions and flight performance requirements were met with ample margins. All electrical functions were performed properly. No Launch Commit Criteria (LCC) or Operations and Maintenance Requirements and Specification Document (OMRSD) violations occurred.

The SRB flight structural temperature response was as expected. Postflight inspection of the recovered hardware indicated that the SRB thermal protection system (TPS) performed properly during ascent with very little TPS acreage ablation.

Separation subsystem performance was normal with all booster separation motors (BSM's) expended and all separation bolts severed. Nose-cap jettison, frustum separation and nozzle jettison occurred normally on each SRB.

The entry and deceleration sequence was properly performed on both SRB's. SRM nozzle jettison occurred after frustum separation, and subsequent parachute deployments were successful. All drogue and main parachutes were recovered.

Three in-flight anomalies were identified based on the observed damage to the SRB's. These anomalies were:

a. Epon shim material was missing from the bottom of the right SRB holddown post (HDP) 3;

b. The right SRB holddown stud at HDP 3 hung up during lift-off, resulting in broaching thread impressions on the bore inside diameter;

c. The left SRB External Tank attachment ring aft integrated electronics assembly end cover experienced hot gas flow (aft to forward) through the interior from the tunnel side, resulting in sooting and varying degrees of heat exposure to 16 operational flight reusable cables.

EXTERNAL TANK

All objectives and requirements associated with the loading and flight operations were met. All ET electrical equipment and instrumentation performed satisfactorily. The operation of the ET heaters and purges was monitored, and all performed properly. No LCC or OMRSD violations were identified.

As expected, only the normal ice/frost formations were observed. There was no ice on the acreage areas of the ET, and only light condensate was present. The ice/frost team reported that no anomalous thermal protection system (TPS) conditions existed. Light-to-moderate ice was reported on the liquid oxygen feedline brackets and the liquid hydrogen and liquid oxygen umbilicals. Balls of frost and light ice were present between the stringers at both intertank interface flanges (-Y and -Z), a condition that is considered normal and acceptable.

This flight marked the fourth time that the prepressurization of the liquid oxygen tank was intentionally reduced by 2 psi (trip level reduced from 20.5 psig to 18.5 psig) to prevent closing of the gaseous oxygen flow control valves during the engine start transient. As planned, the gaseous oxygen flow control valves remained open during the engine start sequence and the early portion of ascent and performed normally throughout the remainder of the flight. The minimum liquid oxygen ullage pressure experienced during the period of the ullage pressure slump was 15.7 psig.

The ET flight performance was excellent. All electrical and instrumentation equipment on the ET performed properly throughout the countdown and flight. The ET tumble system was deactivated for this launch. Entry was normal with breakup and impact within the targeted footprint. No significant ET problems have been identified from the flight.

SPACE SHUTTLE MAIN ENGINE

All SSME parameters appeared to be normal throughout the prelaunch countdown, comparing very well with prelaunch parameters observed on previous flights. Engine ready was achieved at the proper time, and engine start and thrust build-up were normal.

Flight data indicate that SSME performance at main engine start, thrust buildup, mainstage, shutdown and during propellant dump operations was well within specifications. High pressure oxidizer turbopump and high pressure fuel turbopump temperatures were normal throughout the period of engine operation. The SSME controllers provided proper control of the engines throughout powered flight. No failures were noted during the flight, and no significant problems were identified. Engine dynamic data generally compared well with previous flight and test data. All on-orbit activities associated with the SSME's were accomplished successfully.

SHUTTLE RANGE SAFETY SYSTEM

Shuttle range safety system (SRSS) closed-loop testing was completed as scheduled at approximately T-45 minutes in the launch countdown. The SRSS safe and arm devices were armed at T-5 minutes and all system inhibits were turned off at T-10 seconds, as required. Postflight analysis of the SRSS measurements indicates that the onboard systems (ET and SRB) both performed normally. The system signal strength remained above the specified minimum (-97 dBm) for the duration of the flight, except for the right SRB A and B systems and the ET systems which dropped below the specified minimum. The reason for the drop in signal strength is that a lowered transmitted power was used until T+150 seconds after which normal transmitter power was used. This was the planned operation by the range.

ORBITER SUBSYSTEM PERFORMANCE

The Orbiter vehicle supported the mission in a satisfactory manner. A total of 18 Orbiter and Government furnished equipment (GFE) anomalies were identified, none of which impacted the successful completion of the mission.

MAIN PROPULSION SYSTEM

The overall performance of the main propulsion system (MPS) was excellent. No LCC or OMRSD violations were identified. Liquid oxygen and liquid hydrogen loading were performed as planned with no stop flows or reverts. Throughout the preflight operations, no significant hazardous gas concentrations were detected, and the maximum hydrogen levels in the Orbiter aft compartment were 380 ppm, which compares well with previous data.

The calculated liquid hydrogen load at the end of replenish cycle was about +95 lbm more than the inventory load. The calculated liquid oxygen load at the end of replenish cycle was about +597 lbm more than the inventory load. These values represent a loading accuracy for both hydrogen and oxygen of +0.04 percent.

Ascent MPS performance appeared to be completely normal. Preliminary data indicate that the liquid oxygen and liquid hydrogen pressurization systems performed as expected, and that all net positive suction pressure (NPSP) requirements were met throughout the flight. MECO occurred at 506 seconds as predicted.

The engine 3 liquid hydrogen prevalve closed indication (V41X1305E) signal was lost at MECO plus 12.5 seconds. The prevalve close commands are removed at MECO plus 7.56 seconds. When actuation pressure is present, the prevalve relieves pressure through an internal relief valve; however, when pressure is removed, the prevalve relieves pressure by means of a visor liftoff. A pressure of 15 psid across the prevalve is sufficient to cause visor liftoff. When the closed signal was lost, the actuation pressure had been removed and the differential pressure was greater than 15 psid. Based on these conditions, the closed indication is attributed to the pressure differential causing visor liftoff, which is normal system operation.

Trajectory reconstruction indicates that vehicle specific impulse was near the MPS assessment tag values. Ullage pressures were maintained within required limits throughout the flight. Feed system performance was normal, and the liquid oxygen and hydrogen propellant conditions were within the limits during all phases of operation. Propellant dump and vacuum inerting were accomplished satisfactorily.

REACTION CONTROL SUBSYSTEM

The performance of the reaction control subsystem (RCS) was very satisfactory. A total of 4297 lb of propellant was consumed, including the dump to zero percent of the forward module prior to entry. During the RCS hot fire test portion of the flight control system checkout, RCS thruster F1U failed off (Flight Problem STS-33-04a). The thruster fired and was shut down by RM when the chamber pressure transducer reading did not rise above 40 psi within 0.265 second. The chamber pressure indication immediately increased to about 5 psi and remained above zero for 6 to 8 minutes. The injector temperature profile was typical of a normal RCS firing. All temperatures indicated correct operation, expected vehicle rates were produced, and the crew confirmed visually that the thruster fired. Also during entry, the F1U thruster chamber pressure lagged other thrusters by a few psi as the transducers indicated the presence of atmospheric pressure.

ORBITAL MANEUVERING SUBSYSTEM

The OMS operated nominally throughout the mission except for the right-hand oxidizer total quantity reading during the OMS-1 maneuver (Flight Problem STS-33-04d). The gauge read off-scale high during the OMS-1 maneuver and for 10 seconds during the deorbit maneuver. Five OMS maneuvers were performed and all were dual engine firings. A total of 13659 lb of oxidizer and 8264 lb of fuel was used during the maneuvers.

POWER REACTANT STORAGE AND DISTRIBUTION SUBSYSTEM

The power reactant storage and distribution (PRSD) subsystem supported the mission in a nominal manner except for the oxygen tank 1 check valve stuck twice during the mission when the tank was not in use (Flight Problem STS-33-08). The vehicle was flown in the three tank-set configuration. A total of 1162 lb of oxygen and 146.4 lb of hydrogen was used by the fuel cells. In addition, approximately 45 lb of oxygen were used by the environmental control and life support system as breathing oxygen for the five crew members. A 99-hour mission extension was possible at the average power level with the reactants remaining at landing.

The PRSD oxygen tank 1 check valve failed to operate properly at 328:13:03 and 330:10:13 G.m.t. On both occasions when the valve failed to open properly, a 20-psid pressure was required to open the valve. Subsequently, the valve operated nominally at the 3 to 5 psid cracking pressure for the remainder of the time the system was configured with tank 1 and 3 on a common manifold. At 327:12:30 G.m.t., this check valve experienced a large closing force (180 psid) after a high oxygen flow because of the WCS leak.

FUEL CELL POWERPLANT SUBSYSTEM

The fuel cell powerplant subsystem operated satisfactorily throughout the mission, producing 1643 kW of energy at an average power level of 13.6 kW during the 120-hour mission. A total of 1308 lb of water was produced.

Fuel cell operating times were 164 hours 11 minutes, 162 hours 38 minutes, and 162 hours 10 minutes for fuel cells 1, 2 and 3, respectively. Total operational time on these fuel cells is 575 hours 10 minutes, 682 hours 3 minutes, and 1016 hours 15 minutes on fuel cell 1, 2, and 3, respectively. The fuel cells were shut down about 31 hours after landing.

AUXILIARY POWER UNIT SUBSYSTEM

The APU performance was nominal during ascent, flight control system checkout, and entry and landing operations, although four problems occurred during the mission. The following table shows the run time and fuel consumption of each APU during each phase of the flight.

APU no.	Ascent		FCS Checkout		Entry		Total	
	Run time, min	Consumption, lb	Run time, min	Consumption, lb	Run time, min	Consumption, lb	Run time, min	Consumption, lb
1	18.3	50	0.0	0.0	103.6	212	121.9	262
2	18.3	56	7.4	20.0	62.8	160	88.5	236
3	18.3	52	0.0	0.0	62.8	168	81.0	220
	54.9	158	7.4	20.0	229.2	540	291.4	718

During prelaunch operations, APU 3 test line temperature 1 (V46T0183A) cycled up to 88 °F, exceeding the launch commit criteria (LCC) limit of 85 °F. Data show that the heaters were cycling at higher limits. The sensors had been moved from a clamp to a line, making the sensor more sensitive. During previous flights, the upper fault detection annunciation (FDA) limit has been violated for the same reason. The limit will be changed on the vehicle effective with STS-36, and a LCC change has been submitted to change to the new FDA limits.

During ascent, the APU 1 lubrication oil outlet pressure peaked at 85 psia, which is 10 psia above the specification value and about 30 psia above the normal operating range (Flight Problem STS-33-01). After reaching this peak value 9 minutes after lift-off, the pressure decreased to the normal level within 2 minutes. Also, the APU 1 exhaust gas temperature (EGT) 1 sensor (V46T0142A) failed during descent (Flight Problem STS-33-04b), and the APU 3 EGT 2 (V46T0340A) failed during descent (Flight Problem STS-33-04c). None of these anomalies affected the mission.

During postflight evaluation, data showed the system A thermostat for the fuel pump/gas generator valve module (FP/GGVM) heaters on both APU 1 and 3 were operating erratically (Flight Problem STS-33-16). Approximately 24 hours into the flight, the bypass line temperature (V46T0128A) on APU 1 began cycling erratically for about a 6-hour period after which the heater operated nominally. APU 3 bypass line temperature (V46T0328A) also showed erratic heater cycling during the same time period and it lasted for about 6 hours after which it operated nominally. About 20 hours later, more erratic operation was noted and it lasted for about 4 hours before returning to normal operation. A similar scenario was observed on STS-34 when the B system thermostat on FP/GGVM heaters on APU 2 operated erratically and the temperature finally rose above the FDA limit.

HYDRAULICS/WATER SPRAY BOILER SUBSYSTEM

The hydraulics/water spray boiler (WSB) subsystem performance was nominal except that system 1 and 2 priority valves reseated at 2400 psi and 2340 psi, respectively, between 250 lb and 310 lb below the expected level (Flight Problem STS-33-07). This condition was seen on the last two flights (STS-26 and STS-29) of this vehicle. Also, the hydraulic system 2 WSB had a gaseous nitrogen leak (Flight Problem STS-33-17). The gaseous nitrogen tank pressure decayed at a rate of 0.36 lb/hr and the allowable leak rate is 0.3 lb/hr.

PYROTECHNICS SUBSYSTEM

The pyrotechnics subsystem operated nominally during ascent and descent; however, postflight inspection revealed two damaged connectors on the forward ET attach point (Flight Problem STS-33-10).

ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEM

Performance of the environmental control and life support subsystem (ECLSS) was satisfactory. The FES shut down during entry operations when the FES was reconfigured for entry (Flight Problem STS-33-13). The FES was restarted at a higher inlet temperature and operated satisfactorily throughout entry. This shutdown was similar to the one that occurred on STS-29, the last flight of this vehicle. The shutdown did not impact mission operations.

While the waste collection system (WCS) was in use about 12 hours into the mission, the cabin pressure decreased to 14.28 psia before the pressure decrease was stopped (Flight Problem STS-33-02). The cabin leak was isolated to the vacuum/separator valve and, as a result, nominal WCS commode air transport was lost. An IFM procedure, which allowed access to the WCS vacuum/separator valve for manual operation, was implemented by the crew, and full operation of the WCS was successfully regained.

AVIONICS SUBSYSTEMS

The avionics subsystems performed in an acceptable manner; however, several minor problems occurred and these are discussed in the following paragraphs.

The integrated guidance, navigation and control subsystems performed all required functions and operated nominally during prelaunch operations, ascent, on-orbit, descent and entry.

The COAS calibrations that were performed in conjunction with DTO 790 taken on flight day 2, 3 and 4 indicated a shift in the +X COAS line-of-sight by as much as 0.272 degree RSS (Flight Problem STS-33-12). The problem is similar to, but of lesser magnitude than that experienced on STS-29, the last flight of this vehicle.

During final approach, the backup flight system (BFS) exhibited an altitude error greater than 3000 feet. Below 85,000 feet, the BFS does not process no external navigation aids data. The resulting BFS navigation performance usually requires two state vector transfers before heading alignment circle (HAC) acquisition. On STS-33, the transfers were made at 115,000 feet and 41,000 feet. The BFS navigation performance after the second transfer depends on the timing and quality of the last vector transferred as well as inertial measurement unit performance. BFS altitude errors of this magnitude have been observed on the STS-27 and STS-34 missions. In addition, the flight rules allow the incorporation of data from the TACAN and air data transducer assembly (ADTA) into the BFS, if a good navigation state cannot be maintained by the BFS. As a result of these factors, this condition is not considered unusual.

During the flight control system checkout, the Commander's AMI indicator read 20,500 ft/sec and should have read 20,000 ft/sec (Flight Problem STS-33-05). This condition did not impact entry operations.

Two APU exhaust gas temperature sensors failed and these are discussed in the APU section of the report.

The Ku-band antenna failed self-test twice upon initial power-up (Flight Problem STS-33-06). Use of the Ku-band for communications was not impaired by this failure. The self-test was performed once again prior to final stowage and again failed.

The text and graphics system (TAGS) was activated and 10 pages were advanced without problems. About 1 1/2 hours into the mission, three pages were advanced and a jam occurred (Flight Problem STS-33-03). A malfunction procedure was successfully performed and the jam was cleared. However, a jam occurred on the next paper advance. The malfunction procedure was again performed. During this procedure, a paper advance was attempted with the paper advance door opened. No paper motion was observed and the jam lights remained on. The TAGS was turned off and not used for the remainder of the mission.

The microwave scanning beam landing system 3 (ML3) bite toggled on/off several times during entry (Flight Problem STS-33-09). This condition did not impact landing operations.

AERODYNAMICS

The Orbiter vehicle aerodynamic responses were as expected during ascent and entry with no problems being noted. The control surface responses were normal as was the angle-of-attack.

MECHANICAL SUBSYSTEMS

All mechanical subsystems functioned properly. Moderate braking was noted with maximum pressures of about 1100 psig. Preliminary brake energies were nominal and were between 29.7×10^6 ft-lb and 32.7×10^6 ft-lb with braking being initiated at about 147 knots. No brake material was loose, and all brake puck gaps were nominal and exceeded 0.020 inch with most exceeding 0.030 inch. However, inspections of the disassembled brake stack from the left main landing gear revealed some damage to two of the rotors (Flight Problem STS-33-18). The inspections were still in progress at the time of this writing.

The tires showed some signs of wear, but all were in good condition. The left main tires showed little wear, and the nose gear tires looked even better. The right-hand inboard main tire was the worst, but is still acceptable for use in non-flight activities. It is apparent from the inspection that braking and crosswinds added weight to the right-hand side and caused tire chaffing.

THERMAL CONTROL SUBSYSTEM AND AEROTHERMODYNAMICS

The thermal control subsystem (TCS) controlled temperatures were maintained within acceptable limits throughout the mission. The postflight inspections revealed the thermal blanket on the -Y star tracker door was detached from the door and lying in the bottom of the cavity (Flight Problem STS-33-11). There was no door fastener damage, but the blanket had a small tear on the top. The displaced blanket did not affect the mission.

No heater system failures occurred, although two limit violations that resulted for heater operation were noted. During prelaunch activities, the APU 3 service/test line monitoring sensor exceeded the 85 °F upper LCC limit. On-orbit, the starboard RCS fuel tank monitoring sensor reached 91 °F, exceeding the 90 °F upper FDA limit. Neither limit violation resulted from a malfunctioning heater, and efforts are underway to raise these limits. In the area of aerothermodynamics, nominal acreage heating is indicated as a result of the evaluation of the trajectory, vehicle attitudes, and control surface positioning. Nominal local heating is also indicated based on an inspection of the thermal protection subsystem (TPS).

THERMAL PROTECTION SUBSYSTEM

The evaluation showed that the TPS provided protection to the Orbiter based on the structural temperature response data and selected tile surface temperature measurements. The overall boundary layer transition from laminar to turbulent flow was also nominal, occurring 1200 seconds after entry interface. The postflight inspection of the Orbiter revealed no evidence of any overheating on the vehicle. The inspection also showed that the vehicle sustained 118 hits of which 21 had a major dimension of 1 inch or greater, and this damage was about average when compared to previous missions. The 118 hits do not include the base heat shield peppering which is considered minimal. The Orbiter lower surface had 107 hits of which 21 had a major dimension 1 inch or greater. A heavy concentration of hits was observed just aft and inboard of the liquid hydrogen umbilical. The remainder of the lower surface damage was divided equally about the vehicle centerline. A comparison of these numbers to data from 18 previous missions of similar configuration indicates the total number of hits on the lower surface was normal. The damage assessment also indicates that based on severity of damage as shown by surface area and depth measurements, this flight was better than average.

The single largest damage area occurred on the right-hand rudder speed brake and involved two trailing edge tiles, which were probably damaged as a result of the acoustical environment during ascent.

Overall, the reinforced carbon-carbon looked good. The three engine-mounted heat shield thermal blankets were torn. The engine 1 blanket was damaged from the 2:30 to 6:00 o'clock position with stuffing missing from the 5:00 to 6:00 o'clock position. The engine 2 blanket was torn and stuffing was missing from the 12:30 to 1:30 o'clock position. The engine 3 blanket had damage to the outer cover from the 9:00 to 10:00 o'clock position. Orbiter window 5 had two streak deposits. The elevon cove area, upper midfuselage, payload bay doors, and OMS pods all looked nominal with minor to no damage.

The elevon-elevon gap flight demonstration test, in which two new gap filler materials were used to demonstrate potential design changes provided useful information. Results from the test indicated better performance on this flight when compared with the STS-34 flight results. No removal or reworks were identified in this area.

The KSC Shuttle thermal imager (STI) was used to record the kinetic surface temperatures of several areas to establish a postlanding thermal data base. Seventy minutes after landing, the wing reinforced carbon carbon (RCC) panels measured 58 °F, and the nose cap RCC measured 150 °F 11 minutes after landing.

CREW EQUIPMENT AND GOVERNMENT FURNISHED EQUIPMENT

The flight crew equipment and government furnished equipment (GFE) performed nominally except for minor problems with three pieces of equipment.

The 16-mm Arriflex motion picture camera failed to operate (Flight Problem STS-33-15). The crew performed an IFM procedure, but camera operation was not regained. The crew then made a workaround which used vehicle power instead of battery power and the camera operated intermittently for the remainder of the mission.

The COAS readings did not agree by as much as 0.272 degree as discussed in the Avionics Subsystems section of this report.

The galley failed to dispense hot and cold water (Flight Problem STS-33-14a). The crew performed a malfunction procedure that reset the control electronics and regained use of the galley for the rest of the mission.

During postflight crew debriefings, the crew reported the galley rehydration station slide became intermittently stuck during operations (Flight Problem STS-33-14b). The crew lubricated the slide valve with "Chapstick" after which the valve operated smoothly. An evaluation of the slide valve will be made during postflight turnaround activities.

PHOTOGRAPHIC AND VIDEO ANALYSIS

A total of 25 video cameras recorded the launch and ascent of STS-33. Analysis of data from these cameras revealed no anomalies. Video data of landing were also obtained from seven cameras, and an analysis of these data showed no anomalies.

A total of 65 launch films from 35-mm and 16-mm cameras were reviewed, and no Orbiter anomalies were identified. Because of the night launch, no CastGlance or other aircraft coverage of launch and ascent were obtained. Six films of landing operations were also obtained, but these films are awaiting review at the time of this writing.

One SRB anomaly was noted in the launch-pad films from cameras E-10 and E-27. These films show the holddown post bolt at position M-3 hung up at lift-off. This anomaly is discussed in more detail in the SRB section of this report. The analysis of launch films showed some debris, but none that was significant. Circulation was visible on a number of films taken between 95 and 112 seconds after lift-off, and analysis will be made of this phenomenon.

DEVELOPMENT TEST OBJECTIVES AND DETAILED SUPPLEMENTARY OBJECTIVES

Thirteen development test objectives (DTO's) were assigned to the STS-33 mission, and data were collected for ten of the DTO's. Nine detailed supplementary objectives (DSO's) were assigned and all were completed.

DEVELOPMENT TEST OBJECTIVES

DTO 301D - Ascent Structural Capability - The objective of DTO 301D is to evaluate the Shuttle structural capability at (or near) design conditions during lift-off and ascent. Data were recorded for these periods of flight, and the evaluation is underway at the time of this writing.

DTO 305D - Ascent Compartment Venting Evaluation - The objective of DTO 305D is to collect data under operational conditions to evaluate and upgrade Orbiter ascent venting models, and to verify the capability of the vent system to maintain compartment pressures. Data were recorded for the periods of interest, and the evaluation is underway at the time of this writing.

DTO 306D - Descent Compartment Venting Evaluation - The objective of DTO 306D is identical to DTO 305D, except data are collected during descent. Data were recorded for the period of interest, and the evaluation is underway at the time of this writing.

DTO 307D - Entry Structural Capability - The objective of DTO 307D is identical to DTO 301D, except data are being collected during descent. Data were recorded during the period of interest, and the evaluation is underway at the time of this writing.

DTO 308D - Vibration and Acoustic Evaluation - The objective of DTO 308D is to obtain vibration and acoustical data during ascent to define the operational vibro/acoustic input to payloads and the payload deployment and retrieval system. Data were recorded during the period of interest, and the evaluation is underway at the time of this writing.

DTO 311D - POGO Stability Performance.- DTO 311D is designed to obtain longitudinal-oscillation (POGO) related data so that POGO stability margins during operational conditions may be evaluated. Data were collected and are being evaluated. Sponsors for each individual DTO is responsible for publishing the results of their evaluation.

DTO 318 - Direct Insertion ET Tracking.- DTO 318 was not performed as a direct insertion was not made.

DTO 517 - Hot Nosewheel Steering Runway Evaluation - DTO 517 was not performed.

DTO 518 - Revised Braking System Test - DTO 518 was not performed.

DTO 630 - Camcorder Evaluation - The objective of DTO 630 was to evaluate a video camcorder in the space environment as well as the ability to record data with the camcorder. This DTO was performed and data are being evaluated at the time that this report is being written.

DTO 790 - IMU Reference Recovery Techniques - DTO 790 is designed to test IMU reference recovery techniques on orbit. The crew used the COAS and universal pointing software to perform these tests. This DTO was successfully performed, and the data, which consists of crew evaluations and torquing angles obtained from the normal guidance, navigation and control downlist, are being evaluated.

DTO 792 - SRB Rate Gyro Relocation - DTO 792 is designed to define a flight test program that evaluates the performance of a SRB rate gyro assembly located in the Orbiter vehicle midbody. Data were recorded during launch and first stage operations and will be evaluated.

DTO 805 - Crosswind Landing Performance - DTO 805 was not performed.

DETAILED SUPPLEMENTARY OBJECTIVE

DSO 450 - Salivary Cortisol Levels During the Acute Phases of Space Flight - DSO 450 was performed and data are being evaluated at the time of this writing.

DSO 462 - Noninvasive Estimation of Central Venous Pressure during Spaceflight - DSO 462 was performed and data are being evaluated at the time of this writing.

DSO 463 - In-flight Holter Monitoring - DSO 463 was performed and data are being evaluated at the time of this writing.

DSO 466 - Preflight and Postflight Cardiovascular Assessment - DSO 466 was performed and data are being evaluated at the time of this writing.

DSO 467 - Influence of Weightlessness on Baroflex Function - DSO 467 was performed and data are being evaluated at the time of this writing.

DSO 468 - Preflight Adaptation Training - DSO 468 was performed and data are being evaluated at the time of this writing.

DSO 474 - Retinal Photography - DSO 474 was performed and data are being evaluated at the time of this writing.

DSO 475 - Muscle Biopsy - DSO 475 was performed and data are being evaluated at the time of this writing.

TABLE I.- STS-33 SEQUENCE OF EVENTS

Event	Description	Actual time, G.m.t.
APU activation	APU-1 GG chamber pressure	327:00:18:43.02
	APU-2 GG chamber pressure	327:00:18:45.86
	APU-3 GG chamber pressure	327:00:18:49.59
SRB HPU activation	LH HPU system A start command	327:00:23:02.20
	RH HPU system A start command	327:00:23:02.49
	LH HPU system B start command	327:00:23:02.33
	RH HPU system B start command	327:00:23:02.64
Main propulsion System start	Engine 3 start command to EIU	327:00:23:23.465
	Engine 2 start command to EIU	327:00:23:23.561
	Engine 1 start command to EIU	327:00:23:23.690
SRB ignition command (lift-off)	SRB ignition command to SRB	327:00:23:29.986
Throttle up to 104 percent thrust	Engine 3 command accepted	327:00:23:34.185
	Engine 2 command accepted	327:00:23:34.161
	Engine 1 command accepted	327:00:23:34.171
Throttle down to 97 percent thrust	Engine 3 command accepted	327:00:23:50.185
	Engine 2 command accepted	327:00:23:50.162
	Engine 1 command accepted	327:00:23:50.171
Throttle down to 65 percent thrust	Engine 3 command accepted	327:00:24:04.425
	Engine 2 command accepted	327:00:24:04.402
	Engine 1 command accepted	327:00:23:04.412
Throttle up to 104 percent thrust	Engine 3 command accepted	327:00:24:19.626
	Engine 2 command accepted	327:00:24:19.602
	Engine 1 command accepted	327:00:24:19.612
Maximum dynamic pressure (q)	Derived ascent dynamic pressure	327:00:24:32.1
Both SRM's chamber pressure at 50 psi	LH SRM chamber pressure mid-range select	327:00:25:31.23
	RH SRM chamber pressure mid-range select	327:00:25:30.95
End SRM action	LH SRM chamber pressure mid-range select	327:00:25:33.655
	RH SRM chamber pressure mid-range select	327:00:25:33.207
SRB physical separation	SRB physical separation	
	LH APU A turbine speed LOS*	327:00:25:36.75
	LH APU B turbine speed LOS*	327:00:25:36.79
	RH APU A turbine speed LOS*	327:00:25:36.79
	RH APU B turbine speed LOS*	327:00:25:36.83
Throttle down for 3g acceleration	Engine 3 command accepted	327:00:31:01.552
	Engine 2 command accepted	327:00:31:01.534
	Engine 1 command accepted	327:00:31:01.505
3g acceleration	Total load factor	327:00:31:01.6
MECO	MECO command flag	327:00:31:56.1
	NECO confirm flag	327:00:31:56.9
ET separation	ET separation command flag	327:00:32:14.0

* = loss of signal

TABLE I.- CONCLUDED

Event	Description	Actual time, G.m.t.
OMS-1 ignition	Left engine bi-prop valve position	327:00:33:55.4
	Right engine bi-prop valve position	327:00:33:55.4
OMS-1 cutoff	Left engine bi-prop valve position	327:00:35:01.4
	Right engine bi-prop valve position	327:00:35:01.4
APU deactivation	APU-1 GG chamber pressure	327:00:37:01.14
	APU-2 GG chamber pressure	327:00:37:03.14
	APU-3 GG chamber pressure	327:00:37:04.24
OMS-2 ignition	Left engine bi-prop valve position	327:00:57:10.8
	Right engine bi-prop valve position	327:00:57.10.8
OMS-2 cutoff	Left engine bi-prop valve position	327:00:58:46.0
	Right engine bi-prop valve position	327:00:58:46.0
Flight control system checkout		
APU start	APU-2 GG chamber pressure	329:23:59:08
APU stop	APU-2 GG chamber pressure	330:00:06:34
APU activation for entry	APU-1 GG chamber pressure	331:23:05:49.11
	APU-2 GG chamber pressure	331:23:46:48.03
	APU-3 GG chamber pressure	331:23:46:51.27
Deorbit maneuver ignition	Left engine bi-prop valve position	331:23:10:50.1
	Right engine bi-prop valve position	331:23:10:50.1
Deorbit maneuver cutoff	Left engine bi-prop valve position	331:23:13:52
	Right engine bi-prop valve position	331:23:13:52
Entry interface (400k)	Current orbital altitude above reference ellipsoid	331:23:59:47.9
Blackout end	Data locked at high sample rate	No blackout because of TDRS
Terminal area energy management	Major mode change	332:00:23:41.0
Main landing gear contact	RH MLG tire pressure 1	332:00:30:15.9
	LH MLG tire pressure 1	332:00:30:15.9
Main landing gear weight on wheels	LH MLG weight on wheels	332:00:30:17.9
	RH MLG weight on wheels	332:00 30:19.2
Nose landing gear contact	NLG tire pressure 1	332:00:30:25.9
Wheels stop	Velocity with respect to runway	332:00:31:02
APU deactivation	APU-1 GG chamber pressure	332:00:49:35.49
	APU-2 GG chamber pressure	332:00:49:36.44
	APU-3 GG chamber pressure	332:00:49:37.64

TABLE II.- STS-33 PROBLEM TRACKING SUMMARY

Number	Title	Reference	Comments
STS-33-01	APU 1 lubrication oil outlet pressure high	327:00:29 IM33RRF01 PR-APU-3-10-0190	APU 1 experienced higher than normal lubrication oil outlet pressures during ascent. Pressure peaked at approximately 85 psi which is approximately 25 to 30 psi higher than normal. Pressure returned to normal just prior to MECO. KSC performed an oil flush, drain, and filter changeout per the OMRSD. Prelaunch waiver WK1495 and WK1477 was approved 11-21-89.
STS-33-02	Cabin leak through waste collection system (WCS)	327:12:30 J3162 IM33RF02	Cabin pressure decreased to 14.28 psia before leak isolation which coincides with WCS usage. Leak verified when commode slide valve was opened and no discernible air flow was noted, and air transport of fecal matter was lost. Crew performed IFM to manually move vacuum ball valve from vacuum position to FAN SEP position, and full operation of the WCS was restored. WCS was inspected at Dryden by vendor as no equipment removal was required. Inspection found broken pin on linkage in valve handle. KSC will perform valve retest per OMRSD.
STS-33-03	Text and graphics system (TAGS) jam indications	328:00:17 328:02:36 PR-COM-3-10-0147	TAGS activated and 10 pages were advanced without problems. Crew reported all pages were black. At 01:25 MET, three pages were advanced causing a jam. Malfunction procedure 2.8A was performed and jam was cleared. TAGS jammed again when paper was advanced. The malfunction procedure was performed a second time, but the jam was not cleared. TAGS was turned off for rest of mission. KSC removed TAGS and sent to JSC for troubleshooting.
STS-33-04	Operational instrumentation:		
(a)	RCS F1U pressure transducer failed	330:00:59 IM33RF03 Chit J3163	RCS F1U chamber pressure transducer failed during FCS checkout. Within bounds of LCC to fly as is. JSC considering inspection and possibly flying as is.
(b)	APU 1 EGT 1 failed	Entry - IM33RF06	APU 1 EGT 1 failed during entry.
(c)	APU 3 EGT 2 failed	Entry - IM33RF07	APU 3 EGT 2 failed during entry.
(d)	Right OMS oxidizer quantity off-scale high	OMS-1 maneuver IM33RF10	Right OMS oxidizer quantity was off-scale high during OMS-1 maneuver, operated nominally during OMS-2. and repeated again for 10 seconds during deorbit maneuver.
STS-33-05	Commander AMI Mach velocity indicator out of specification	330:00:39 IM33RF04 IPR	During FCS checkout, the Commander AMI Mach velocity indicator read 20,500 ft/sec (should be 20,000 ft/sec). KSC performed test prior to software download and problem did not repeat.
STS-33-06	Ku-band failed self-test	IPR 31RV-0003 IM33RF05	Ku-band failed self-test two times during activation. Ku-band operated properly. KSC performed normal OMI checkout at KSC
STS-33-07	Hydraulics system 1 and 2 accumulator pressure locked up low	Ascent CAR33RF08	Low reseat of system 1 and 2 priority valves (2400 and 2340 psi) after APU shutdown. Lockup pressure should have been 2650 psi. Seen on last two previous flights of OV-103.

TABLE II.- STS-33 PROBLEM TRACKING SUMMARY

Number	Title	Reference	Comments
STS-33-08	Cryogenic oxygen tank 1 check valve stuck twice	IM33RF09	Oxygen tank 1 check valve stuck twice during the mission when oxygen tank 1 was not in use. A 20-psid pressure difference across the check valve was built-up before the check valve opened and the check valve returned to normal operation. Nominal cracking pressure is 3 to 5 psid. This phenomena has been seen on previous flights when large closing forces occurred. This check valve experienced a large closing force (180 psid) after a high oxygen flow when the WCS leak was stopped. No special turnaround operations are required, and the check valve will be flown as is. CLOSED
STS-33-09	MSBLS 3 bite (AGC)	Entry IPR 31RV0006 IM33RF11	MSBLS 3 bite (AGC) on entry. Toggled on/off several times. JSC Mission Operations reviewing data. MSBLS removed on 12/18
STS-33-10	Forward attach point system A and B connectors broken	Postlanding inspection PR-PYRO-3-09-0117 IM33RF12	Postlanding inspection of the forward attach point system A and B connectors showed that connector 20V77W11J13 has broken strain relief and connector 20V77W12J12 had loose backshell. Was not torqued. Suspected cause is that the strain reliefs were not aligned. Similar condition noted and corrected on OV-102.
STS-33-11	-Y star tracker blanket detached	Postlanding inspection IM33RF13 IPR 31RV0005	-Y star tracker thermal blanket was found totally detached from the door and lying loose in the bottom of the cavity. No fastener damage. Small tear on top of the blanket. Possibility that door was closing when blanket was damaged. MCR 1626 to delete blanket from star tracker door installation. CLOSED
STS-33-12	+X COAS line-of-sight variations	IM33RF14	+X COAS line-of-sight was varying from day to day. Maximum shift noted was 0.272 degree RSS. Review of IMU attitude errors confirm they do not account for total shift. SODB specification for COAS reinstallation is 20 arc seconds/axis. This problem is similar to the COAS problem on STS-29.
STS-33-13	FES B outlet temperature oscillations	Entry IM33RF15	FES shutdown occurred during entry preparations when the FES was reconfigured to Primary B GPC. The outlet temperature cycled during startup and caused auto shutdown. A restart at a higher inlet temperataure was successful. This same condition occurred during STS-29 entry preparations.
STS-33-14	Galley problems		
(a)	Failure to dispense hot and cold water	On-orbit	Galley failed to dispense hot and cold water through the rehydration station. Malfunction procedure worked and function restored.
(b)	Rehydration station slide valve sticky	On-orbit	Slide valve sticky, but worked satisfactorily after crew lubricated slide with "Chapstick". JSC/GFE personnel to clean and lubricate as required

TABLE II.- STS-33 PROBLEM TRACKING SUMMARY

Number	Title	Reference	Comments
STS-33-15	16-mm Arriflex camera inoperative	On-orbit	IFM procedures didn't recover camera. Battery pack was removed and spacecraft power was used. Camera recovered.
STS-33-16	APU 1 and 3 bypass line A temperatures erratic	On-orbit	Heaters controlled by A thermostats on APU-1 and APU-3 bypass lines were erratic indicating changing thermostat set points. Thermostats are mounted on bypass lines which experienced vibrations that loosened the thermostat mounting. Thermostats will be removed and replaced.
STS-33-17	Hydraulic system 1 and 2 water spray boiler gaseous nitrogen pressure decay	On-orbit	The hydraulic system 2 water spray boiler (WSB) exhibited gaseous nitrogen leakage during on-orbit operations. The gaseous nitrogen tank pressure decayed approximately 0.36 psi/hr. The allowable leak rate is 0.3 psi/hr. Repeat of problem seen on system 1 during STS-26
STS-33-18	Left main landing gear brake damage	Landing	Some brake rotor damage was noted during disassembly of the brake stack from the left main landing gear.

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